

Hydro-meteorological forecasts for precise irrigation: the impact on hydrological variables



Moloch	spatial resolution: ~ 1.5 km, Δt 1h, forecast horizon +45h
Bolam	spatial resolution: ~ 11 km, Δt 1h, forecast horizon +72h



ECMWF (deterministic)	spatial resolution: ~ 10 km, Δt 6h, forecast horizon +240h
ECMWF (50 ens +1)	spatial resolution: ~ 20 km, Δt 6h, forecast horizon +360h 50 ensembles + 1 unperturbed run
WRF (deterministic)	spatial resolution: ~ 3 km, Δt 1h, forecast horizon +96h



WRF (8 multi-model runs)	spatial resolution: ~ 5.5 km, Δt 1h, forecast horizon +72h, 8 ensembles
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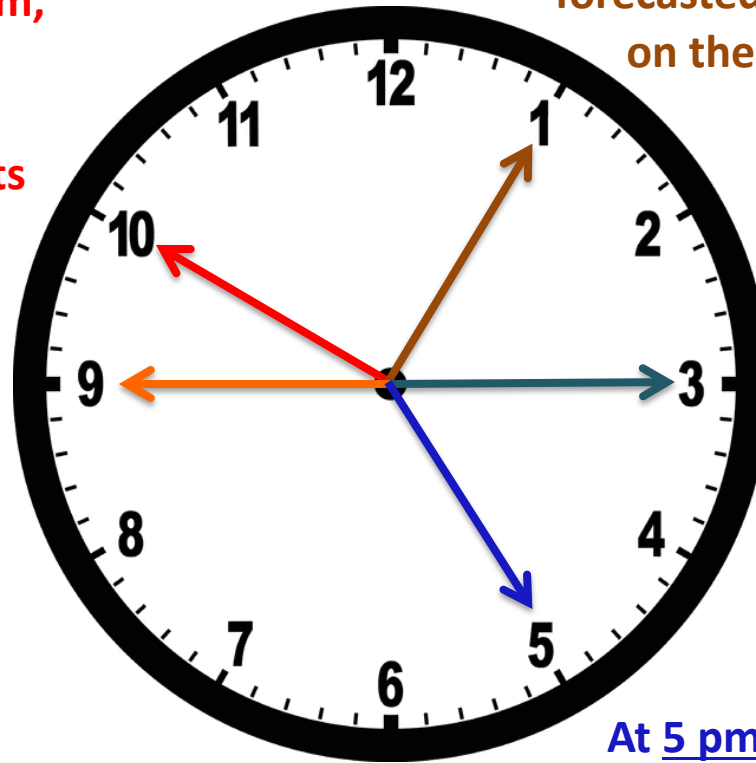


The SIM hydro-meteorological chain



At 10 am: get the deterministic runs (Bolam, Moloch, WRF-UIB) to generate hydro-meteorological forecasts

At 9 am: get the Meteonetwork data to initialize the FEST-EWB model



At 1 pm: observed and forecasted data are uploaded on the SIM dashboard

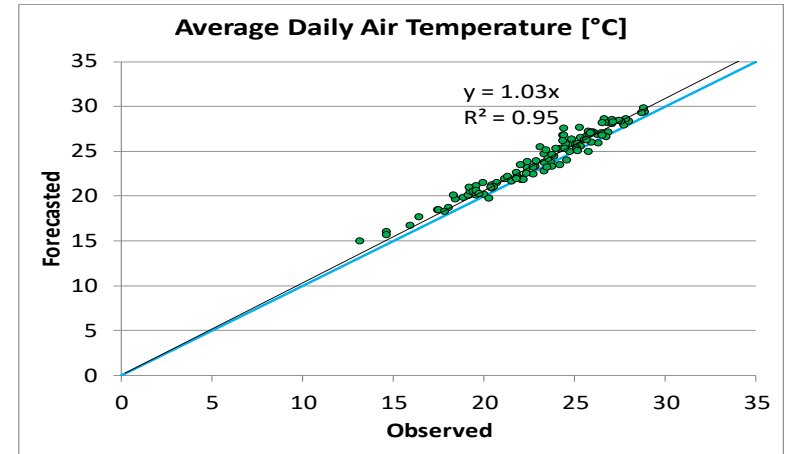
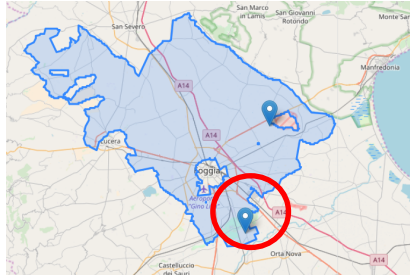
At 3 pm: get the WRF-MOPI runs to generate hydro-meteorological forecasts

At 5 pm: WRF-MOPI forecasted data are uploaded on the SIM dashboard



CPU information:

1 Processor Intel Xeon (6 Cores, 12 threads)
32 GB ECC RAM
Hard Disk: Primary 256 GB SDD
Secondary: 9.1 TB Array of 5 Hard Disk in Raid-5 Configuration
NAS: 14 TB Array of 5 Hard Disk in Raid-5 Configuration



1) Scatter plots

2) Mean Absolute Error (MAE)

$$MAE = \frac{1}{n} \sum_{i=1}^n |F_i - O_i|$$

3) Correlation Coefficient (R^2)

$$r^2 = \frac{\left(\sum_{i=1}^n (F_i - \bar{F}) \cdot (O_i - \bar{O}) \right)^2}{\sqrt{\sum_{i=1}^n (F_i - \bar{F})^2} \sqrt{\sum_{i=1}^n (O_i - \bar{O})^2}}$$

4) Mean Error (ME)

$$ME = \frac{1}{n} \sum_{i=1}^n (F_i - O_i)$$

where:

F = Forecast

O = Observed



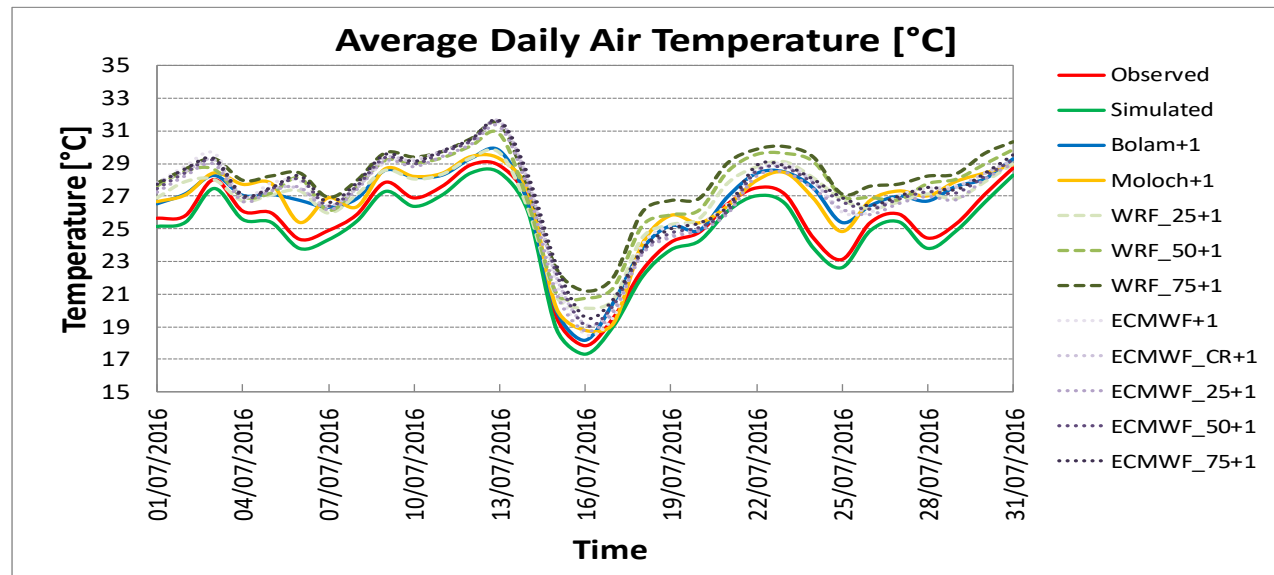
Guzzetti farm

Day +1

MAE	Air Temperature [°C]	Air Humidity [-]	Solar Radiation [W/m ²]	Wind Speed [m/s]	Daily Precipitation [mm]	Soil Moisture [-]	LST [°C]
Simulated	0.53	0.00	33	0.04	4.61	0.03	3.8
Bolam+1	0.81	0.05	56	0.81	1.46	0.03	3.0
Moloch+1	0.88	0.05	56	0.51	1.76	0.03	2.9
WRF_25+1	0.98	0.11	76	0.99	1.41	0.03	2.8
WRF_50+1	1.39	0.08	86	1.44	1.33	0.03	2.4
WRF_75+1	2.07	0.06	101	1.89	1.38	0.03	2.0
ECMWF+1	1.17	0.07	245	0.48	1.52	0.03	3.0
ECMWF_CR+1	1.14	0.06	230	0.56	1.53	0.03	2.9
ECMWF_25+1	0.93	0.07	249	0.54	1.28	0.03	3.1
ECMWF_50+1	1.09	0.06	226	0.52	1.39	0.03	2.9
ECMWF_75+1	1.29	0.05	208	0.56	1.68	0.03	2.7

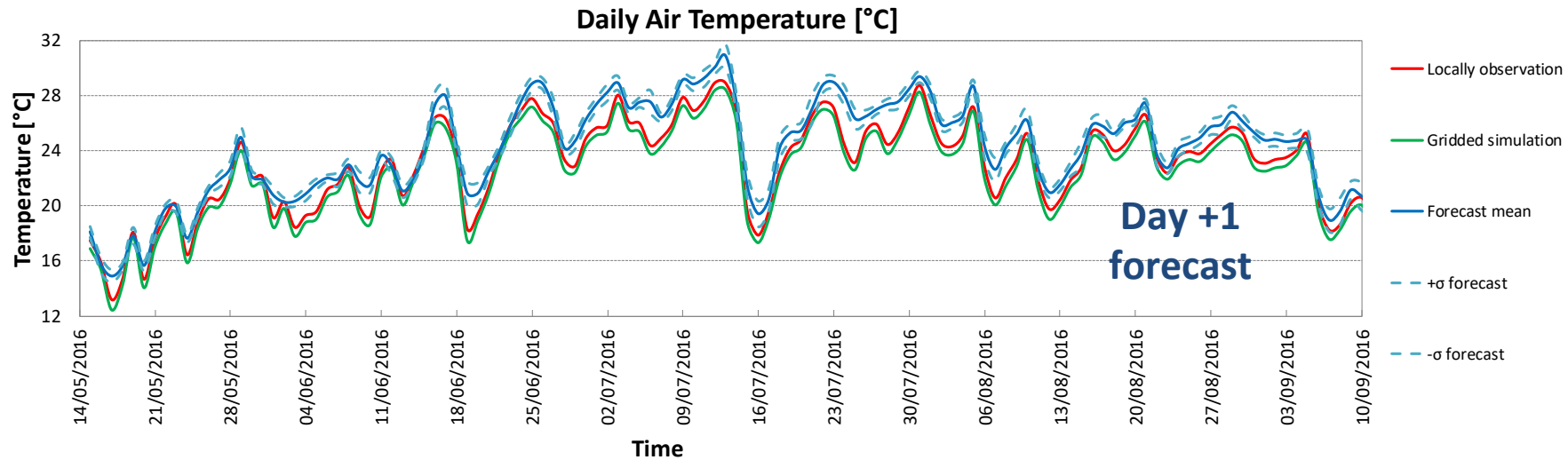
MAE summary

- Air temperature: 0.8-2.1°C
- Air Humidity: 5-11%
- Solar radiation: 50-250 W/m²
- Wind speed: 0.5-1.9 m/s
- Precipitation: 1.3-1.7 mm
- Soil Moisture: 3%
- LST: 2.0-3.1°C

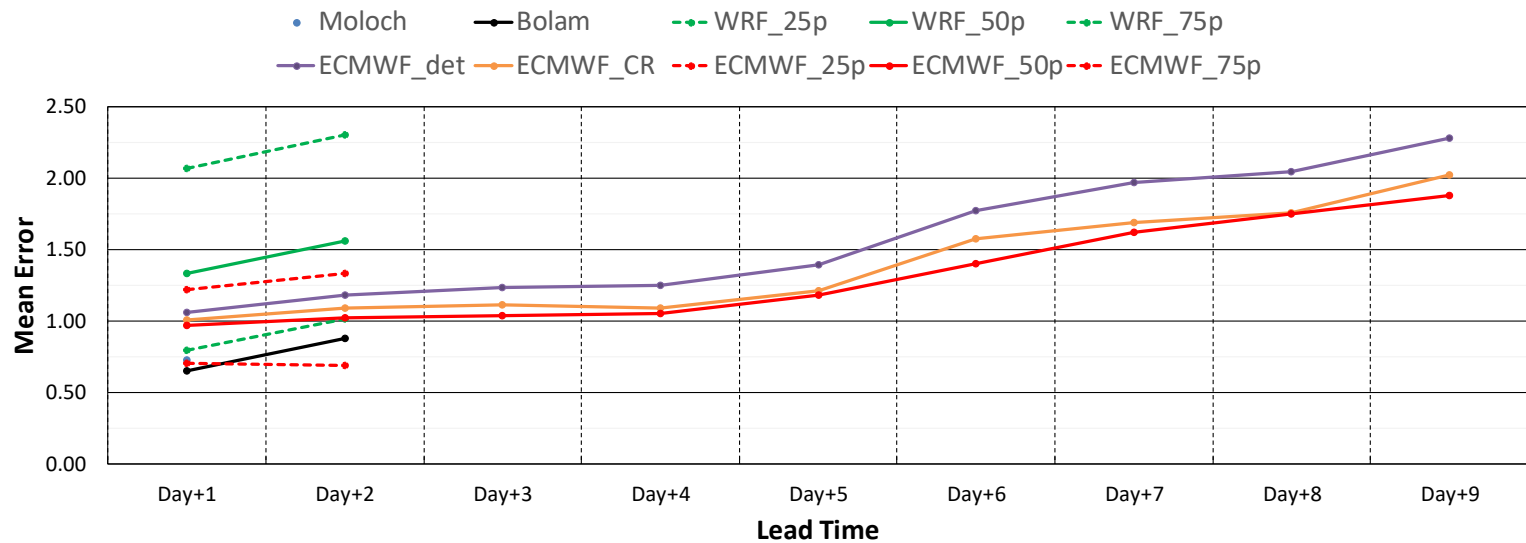




Guzzetti farm



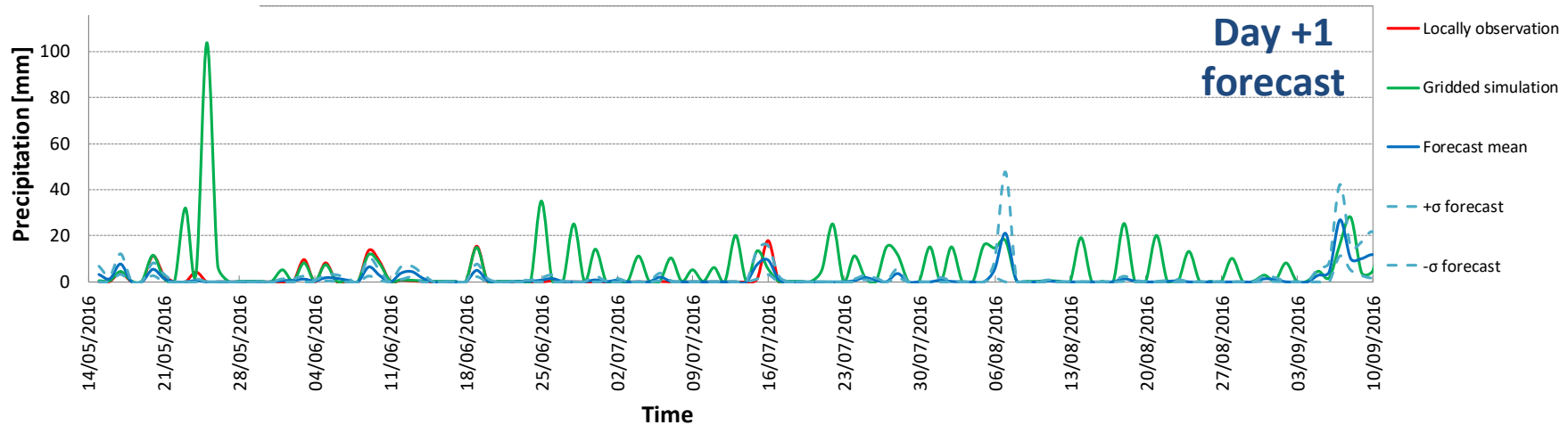
Mean forecast error at a given lead time



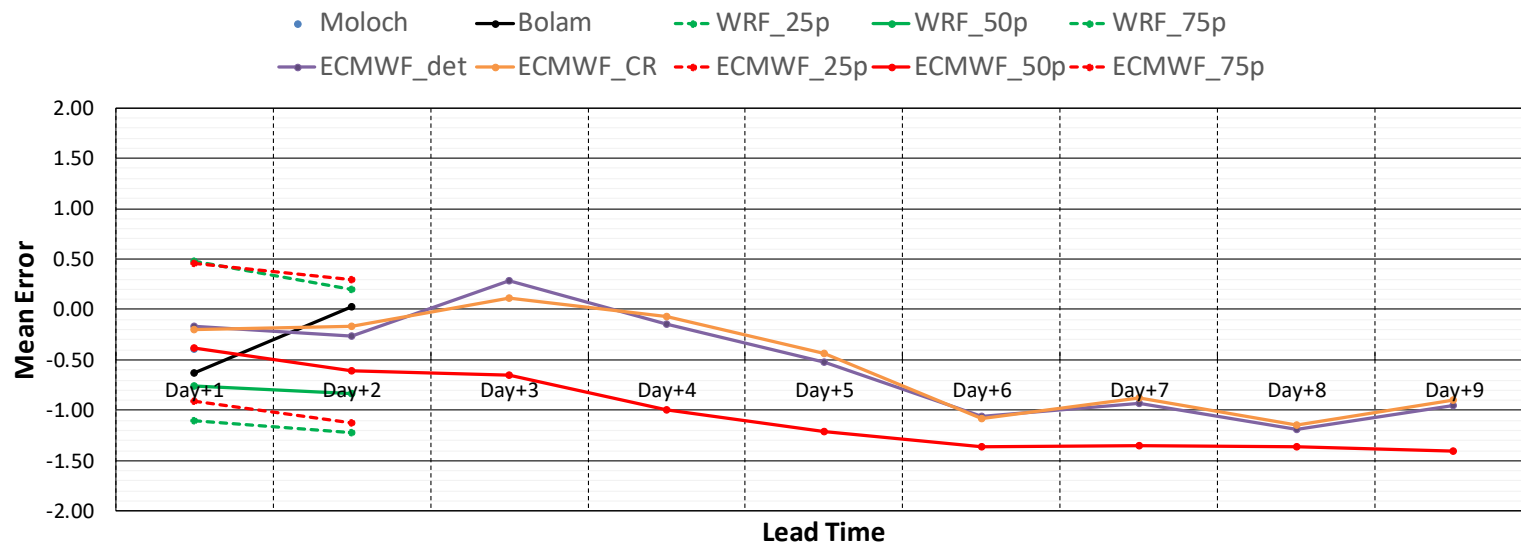


Guzzetti farm

Daily Precipitation [mm]

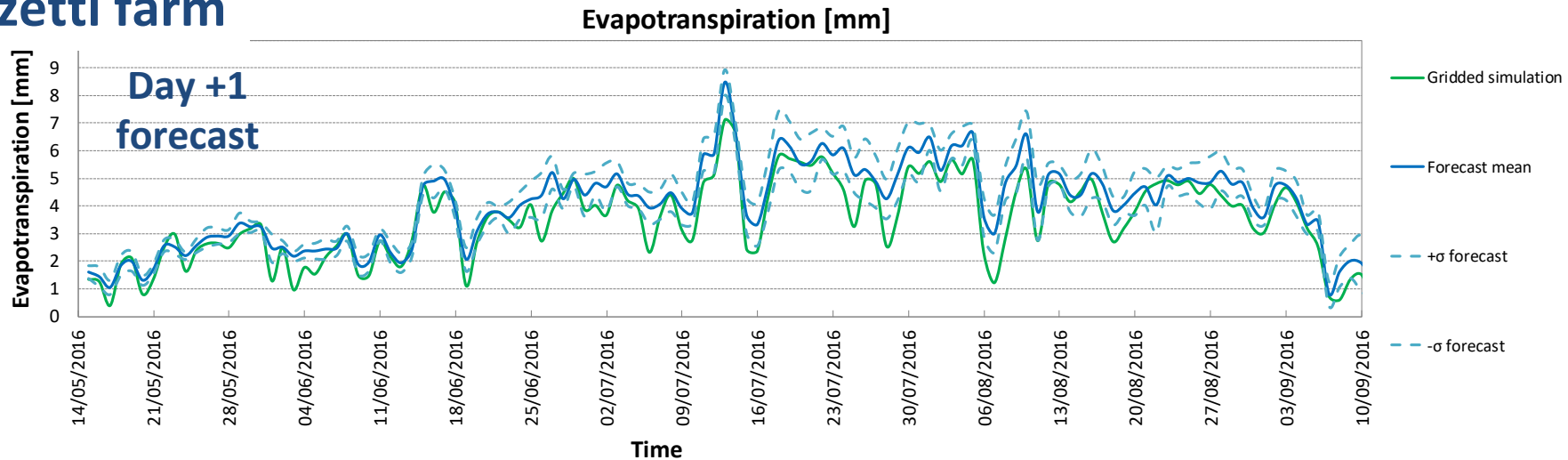


Mean forecast error at a given lead time

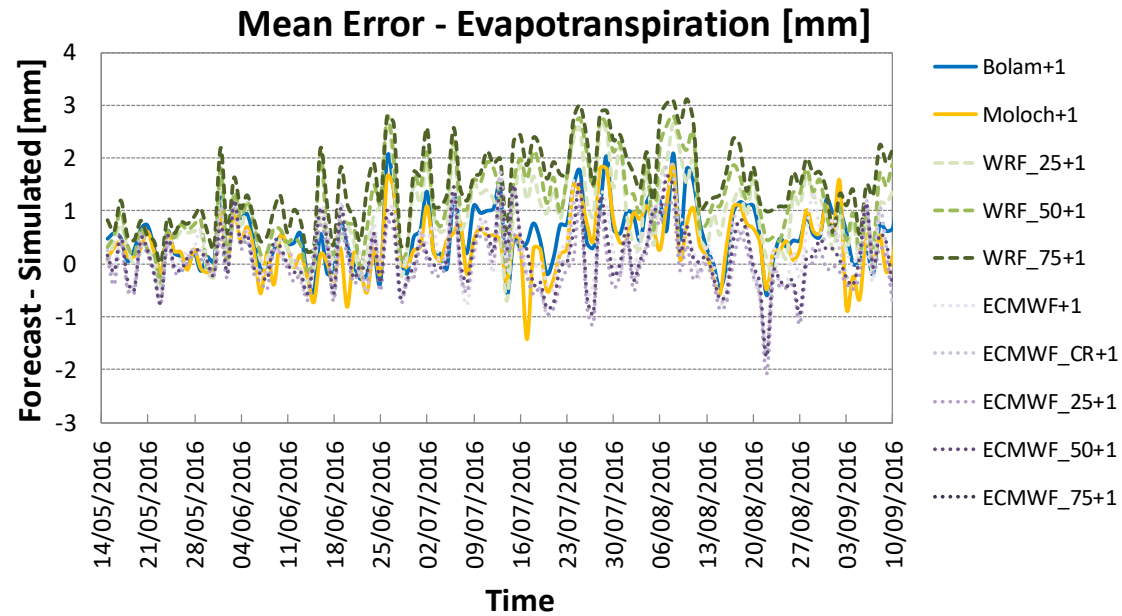




Guzzetti farm



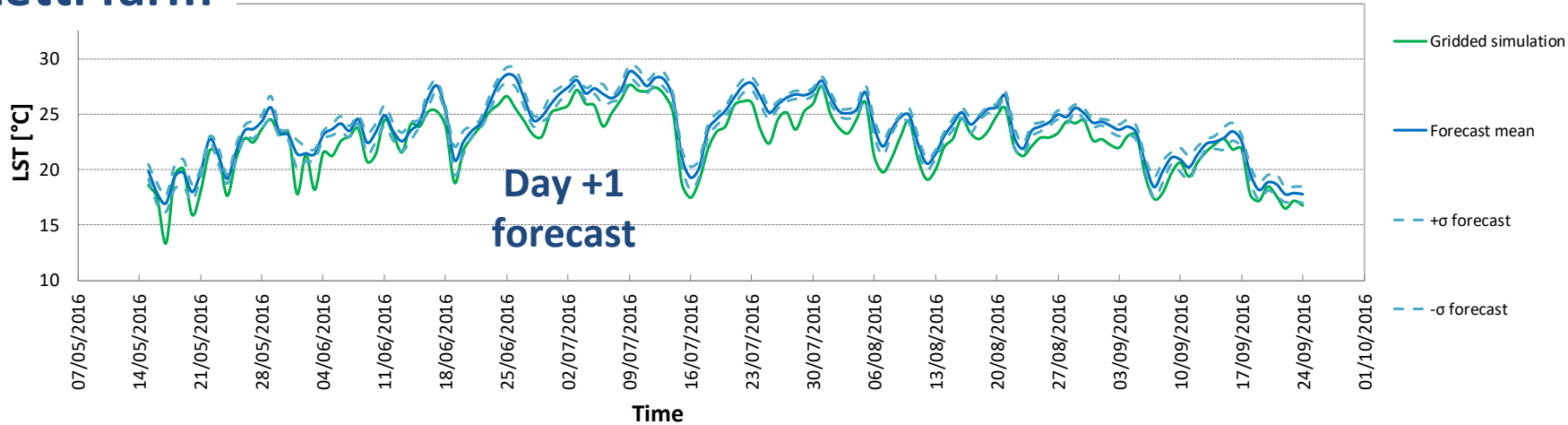
Mean Error	ET [mm]
Bolam+1	0.57
Moloch+1	0.37
WRF_25+1	0.88
WRF_50+1	1.19
WRF_75+1	1.51
ECMWF+1	0.25
ECMWF_CR+1	0.16
ECMWF_25+1	-0.04
ECMWF_50+1	0.16
ECMWF_75+1	0.35





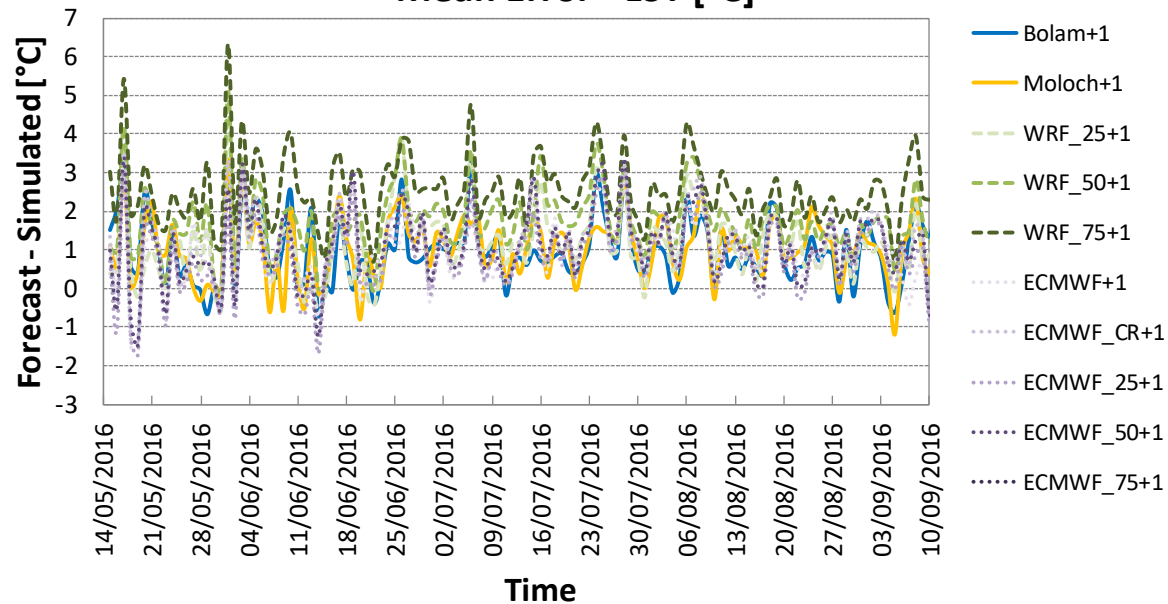
Guzzetti farm

LST [°C]



Mean Error	LST [°C]
Bolam+1	0.9
Moloch+1	1.0
WRF_25+1	1.2
WRF_50+1	1.7
WRF_75+1	2.5
ECMWF+1	0.9
ECMWF_CR+1	1.0
ECMWF_25+1	0.8
ECMWF_50+1	1.0
ECMWF_75+1	1.3

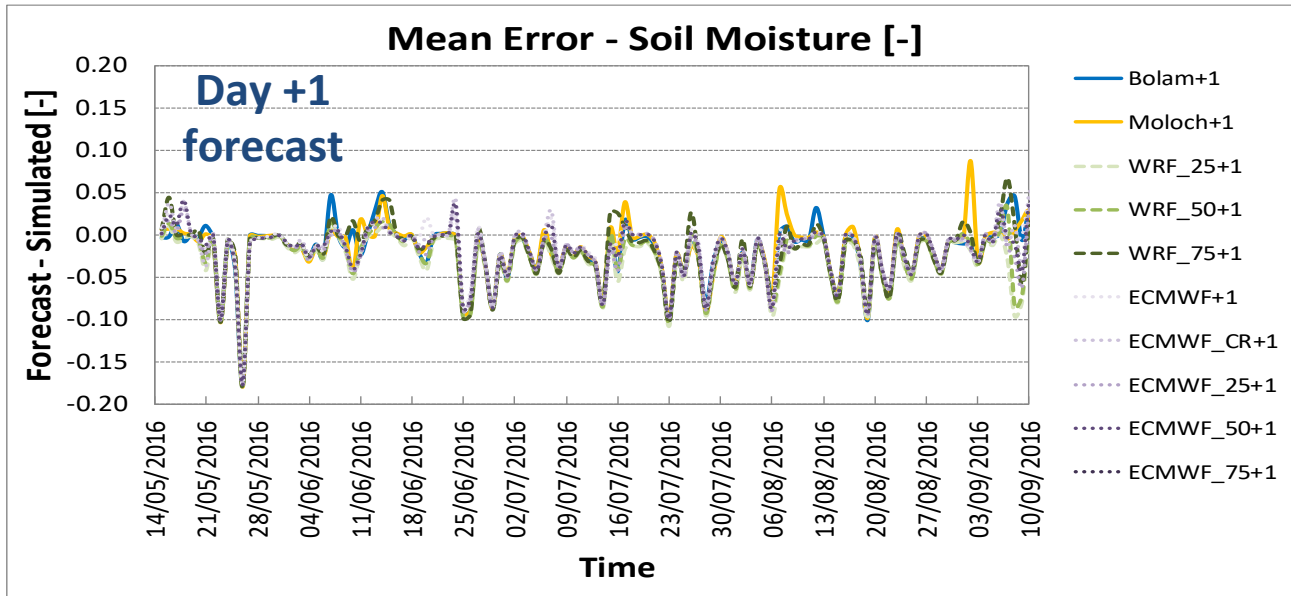
Mean Error - LST [°C]





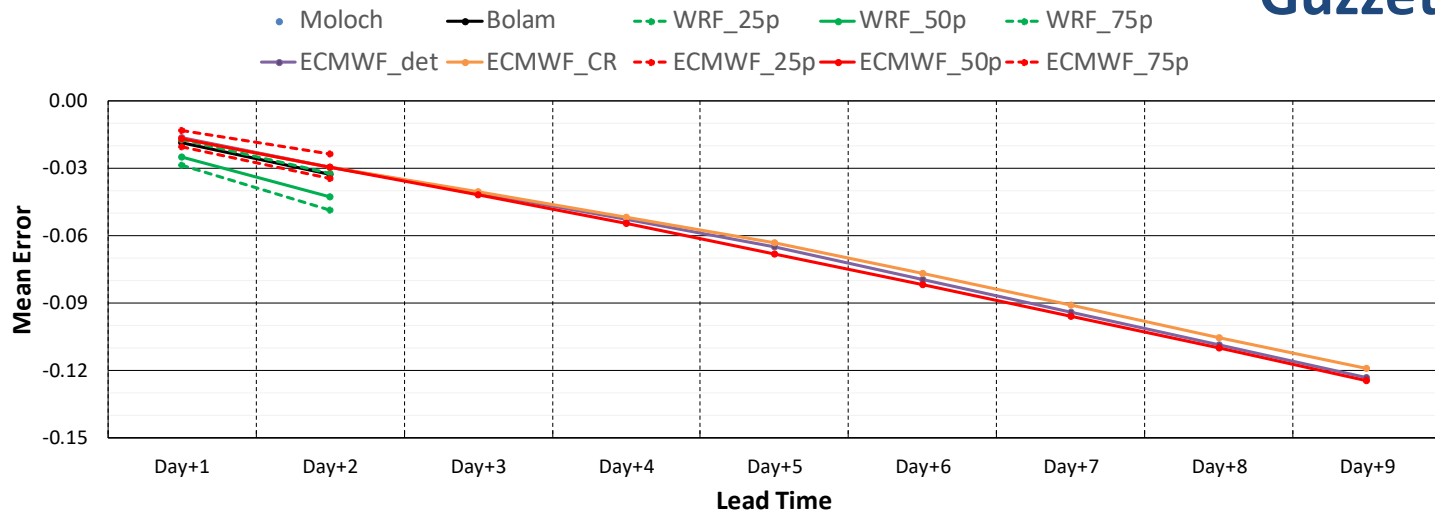
Impact of the forecast model on soil moisture (growing season 2016)

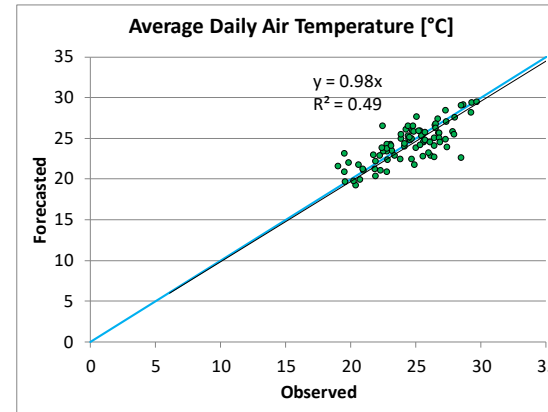
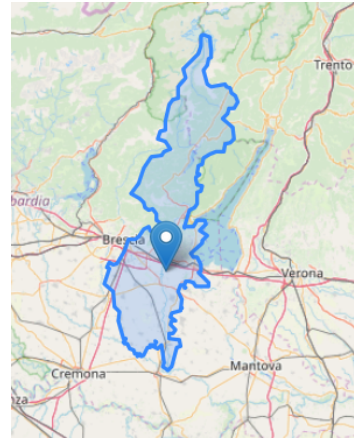
ME	Soil Moisture [-]
Bolam+1	-0.02
Moloch+1	-0.02
WRF_25+1	-0.03
WRF_50+1	-0.03
WRF_75+1	-0.02
ECMWF+1	-0.02
ECMWF_CR+1	-0.02
ECMWF_25+1	-0.02
ECMWF_50+1	-0.02
ECMWF_75+1	-0.01



Mean forecast error at a given lead time

Guzzetti farm





1) Scatter plots

2) Mean Absolute Error (MAE)

3) Correlation Coefficient (R^2)

4) Mean Error (ME)

$$MAE = \frac{1}{n} \sum_{i=1}^n |F_i - O_i|$$

$$r^2 = \left(\frac{\sum_{i=1}^n ((F_i - \bar{F}) \cdot (O_i - \bar{O}))}{\sqrt{\sum_{i=1}^n (F_i - \bar{F})^2} \sqrt{\sum_{i=1}^n (O_i - \bar{O})^2}} \right)^2$$

$$ME = \frac{1}{n} \sum_{i=1}^n (F_i - O_i)$$

where:

F = Forecast

O = Observed



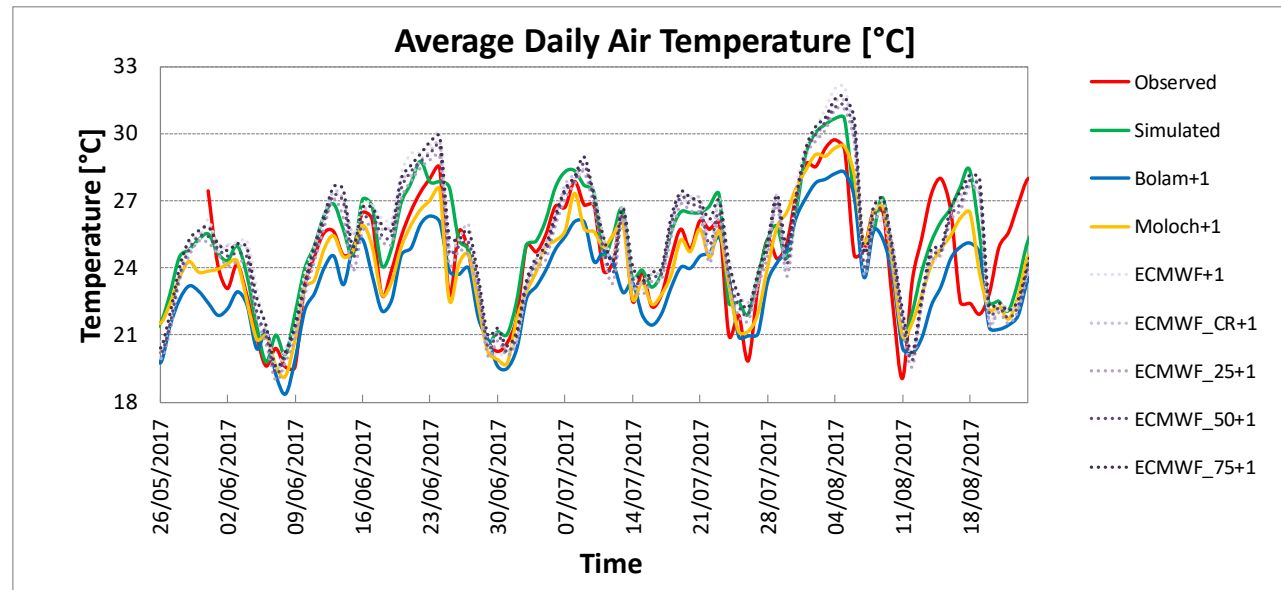
Chiese farm

Day +1

MAE	Air Temperature [°C]	Air Humidity [-]	Solar Radiation [W/m ²]	Wind Speed [m/s]	Daily Precipitation [mm]	Soil Moisture [-]	LST. [°C]
Simulated	1.41	0.06	87	0.37	2.67	0.03	2.1
Bolam+1	1.75	0.06	46	0.87	16.83	0.05	2.9
Moloch+1	1.43	0.08	58	0.98	9.69	0.04	2.4
ECMWF+1	1.79	0.13	284	0.56	3.52	0.04	2.0
ECMWF_CR+1	1.74	0.12	289	0.52	3.16	0.04	2.4
ECMWF_25+1	1.57	0.13	313	0.42	2.70	0.04	2.8
ECMWF_50+1	1.66	0.11	287	0.48	3.01	0.04	2.5
ECMWF_75+1	1.80	0.10	267	0.61	3.79	0.04	2.2

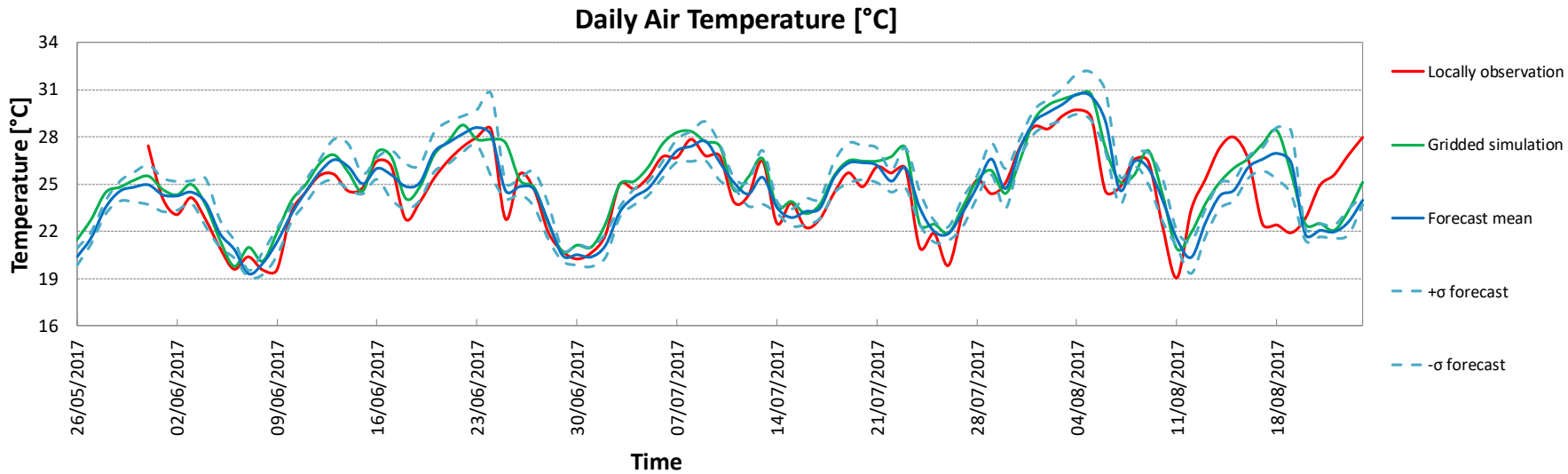
MAE summary

- Air temperature: 1.4-1.8°C
- Air Humidity: 6-13%
- Solar radiation: 50-300 W/m²
- Wind speed: 0.4-1.0 m/s
- Precipitation: 2.5-17 mm
- Soil Moisture: 3-5%
- LST: 2.0-3.0°C

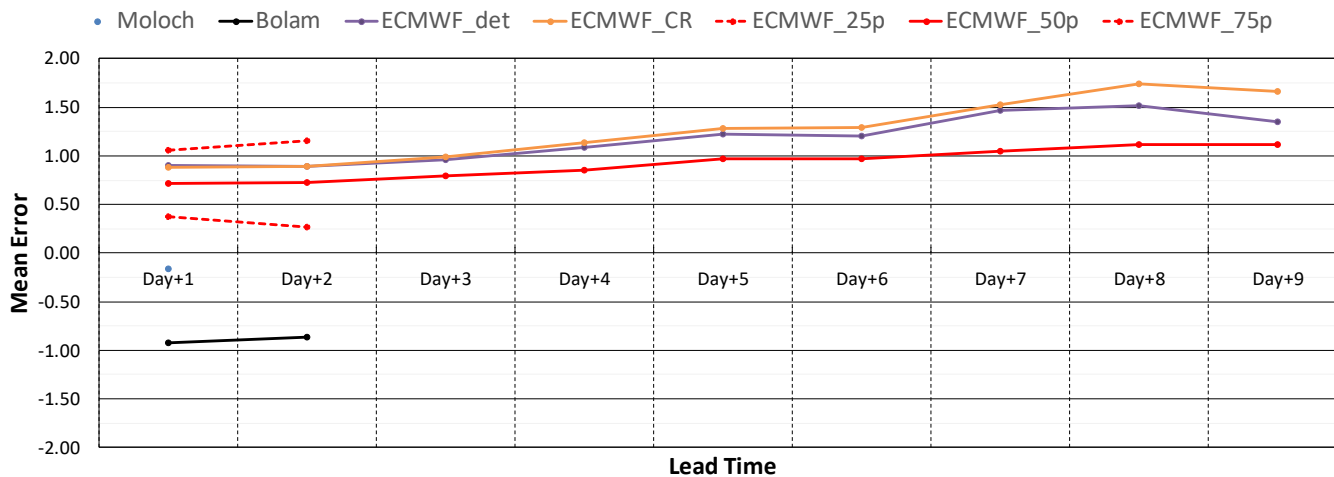




Chiese farm

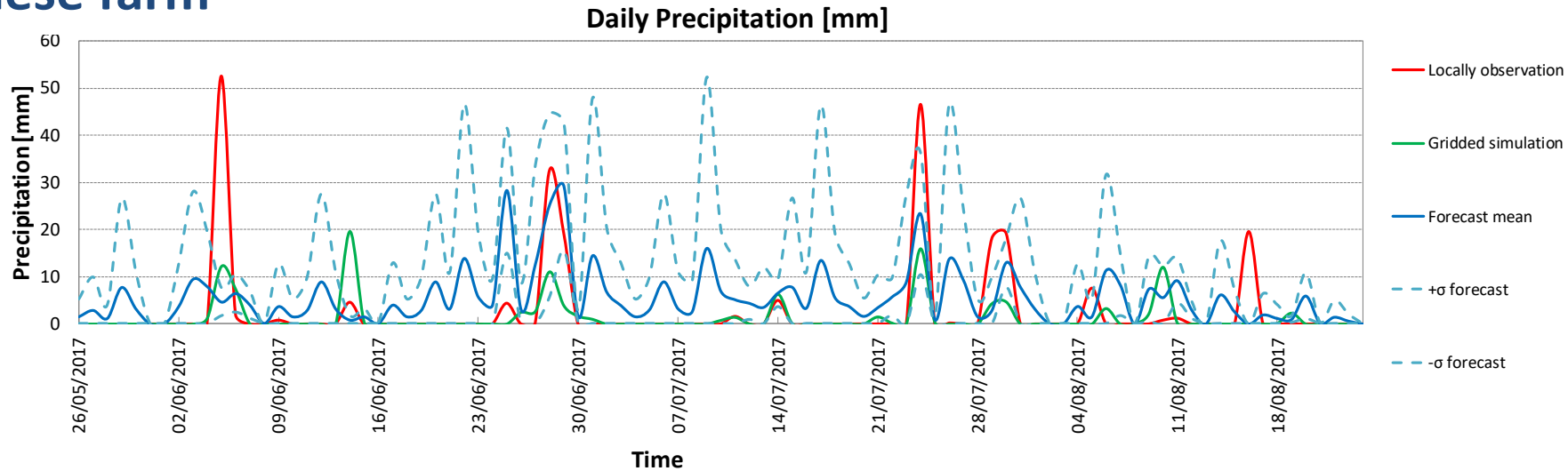


Mean forecast error at a given lead time

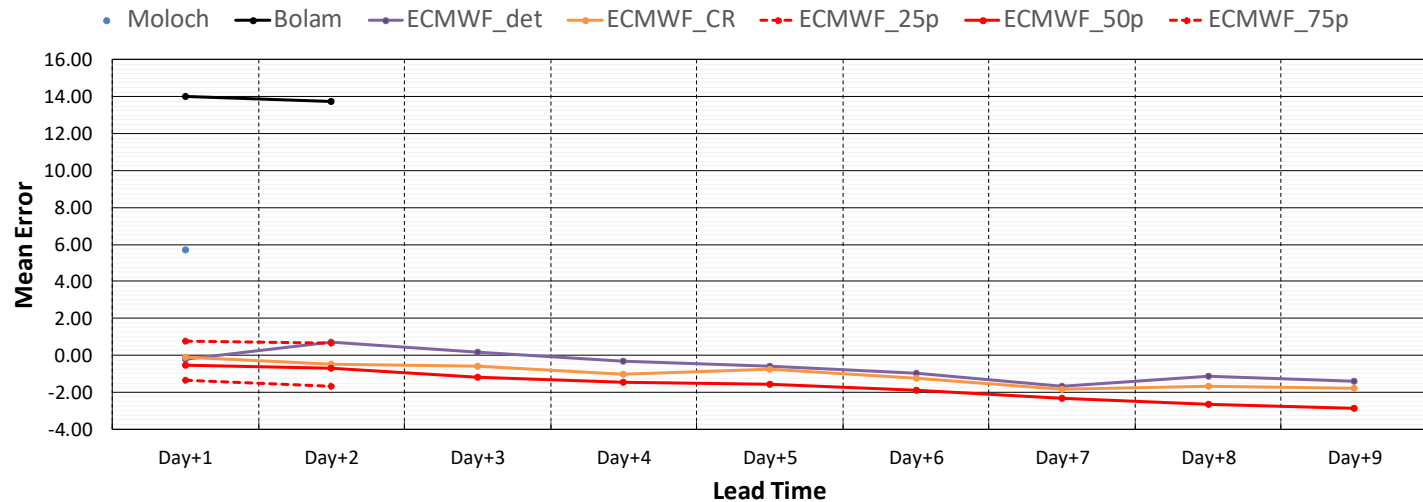


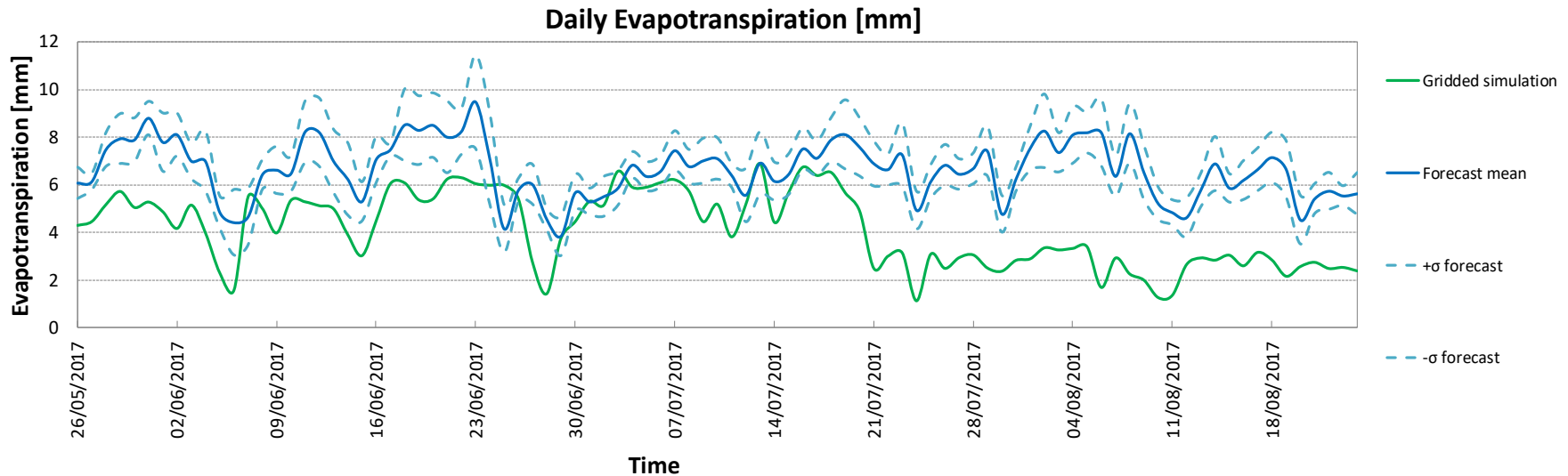


Chiese farm



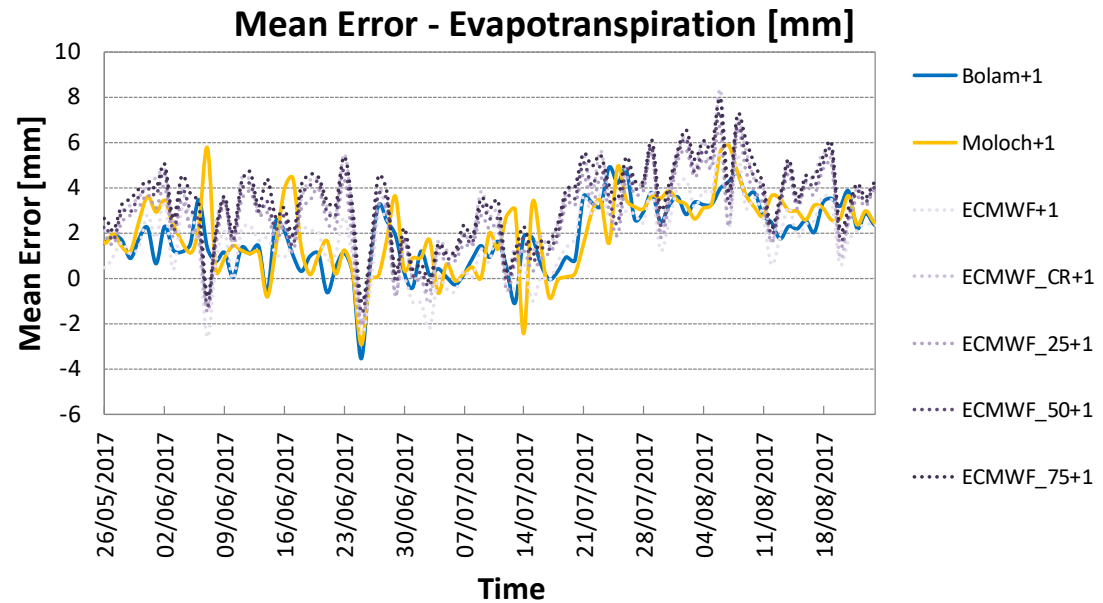
Mean forecast error at a given lead time





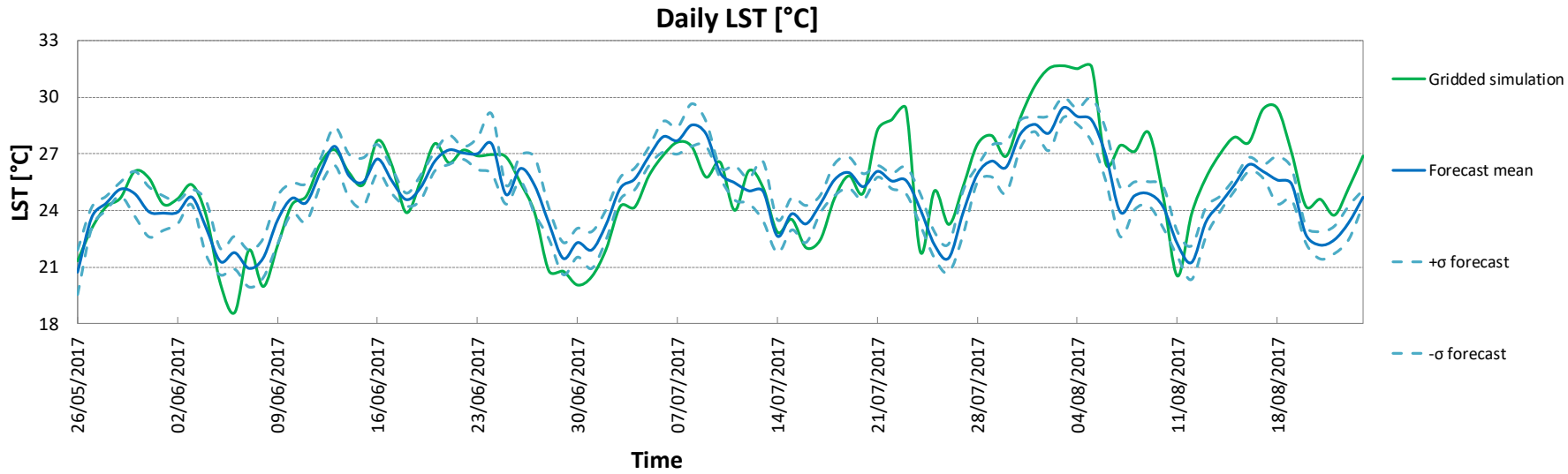
Chiese farm

Mean Error	ET [mm]
Bolam+1	1.66
Moloch+1	1.90
ECMWF+1	1.29
ECMWF_CR+1	2.53
ECMWF_25+1	2.13
ECMWF_50+1	2.49
ECMWF_75+1	2.86



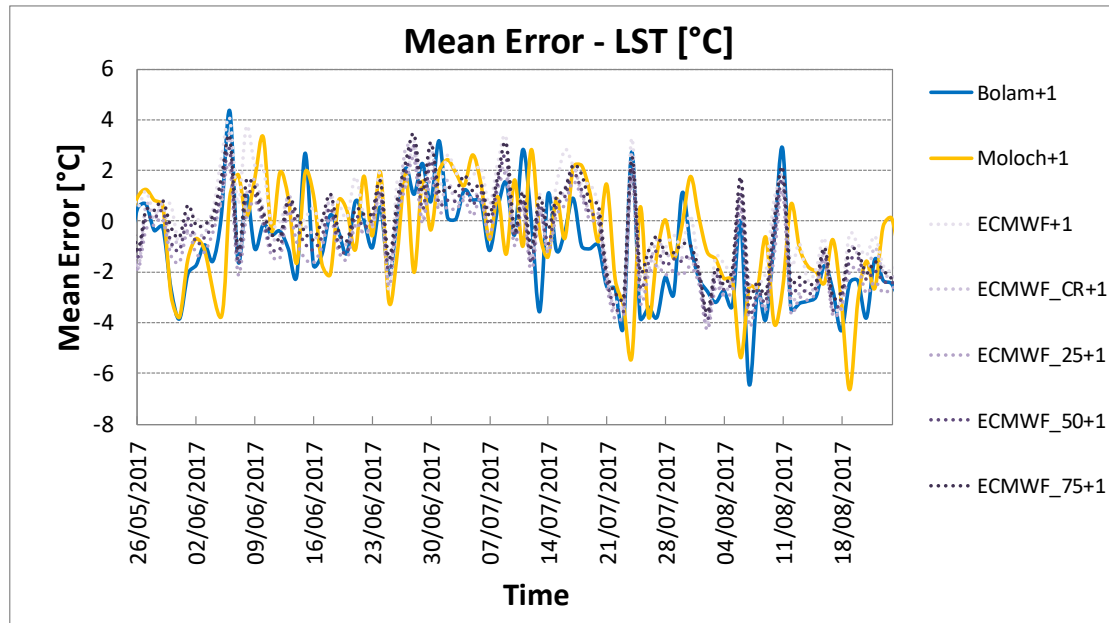


Performance analysis of the growing season 2017



Chiese farm

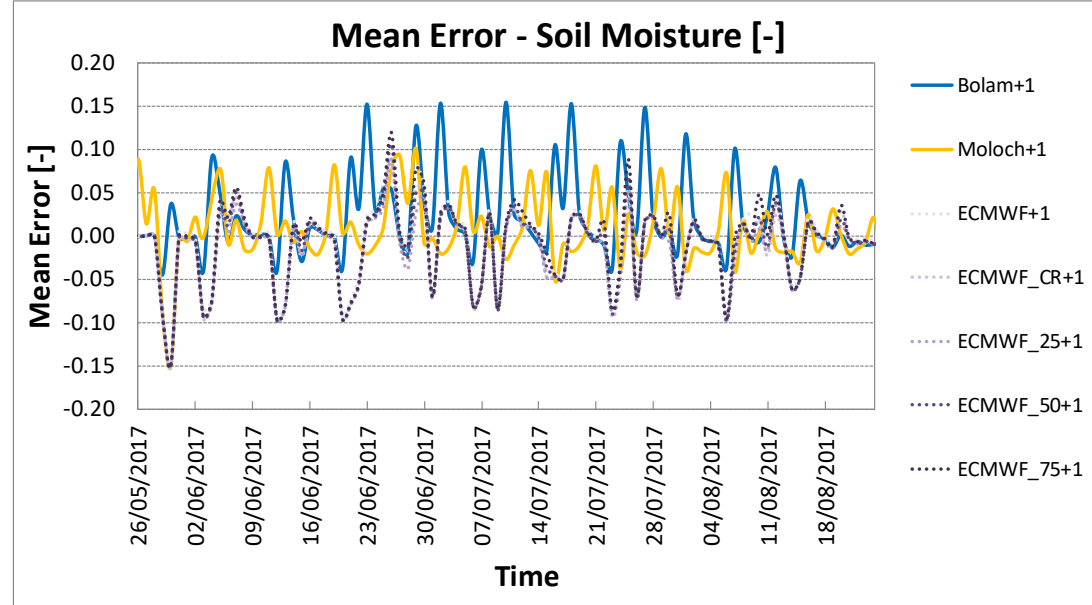
Mean Error	LST [°C]
Bolam+1	-0.9
Moloch+1	-0.5
ECMWF+1	0.0
ECMWF_CR+1	-0.5
ECMWF_25+1	-1.0
ECMWF_50+1	-0.6
ECMWF_75+1	-0.2



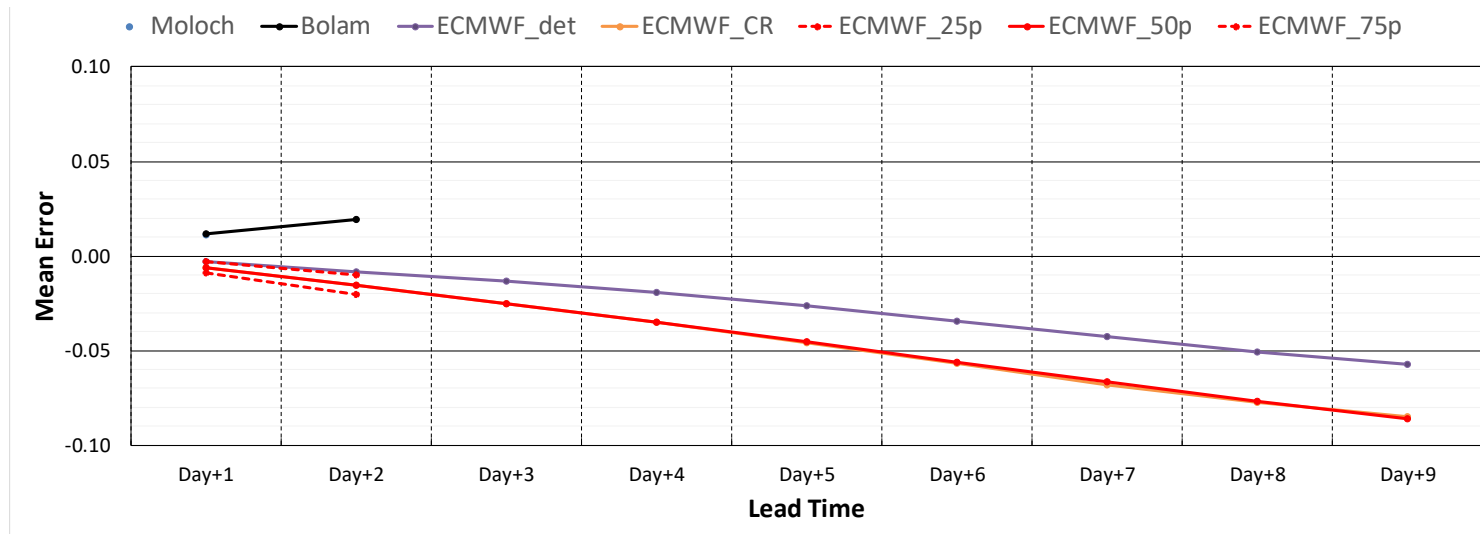


Chiese farm

ME	Soil Moisture [-]
Bolam+1	0.01
Moloch+1	0.01
ECMWF+1	0.00
ECMWF_CR+1	-0.01
ECMWF_25+1	-0.01
ECMWF_50+1	-0.01
ECMWF_75+1	0.00



Mean forecast error at a given lead time



Day +1 forecast